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THRIPS AS POLLINATORS OF BEET FLOWERS.

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INTRODUCTION.

While conducting breeding experiments with sugar beets during a period of more than five years, it could never be observed that the beet flower, despite the pungent fragrance of its nectar and the remarkable abundance of its pollen, attracted nearly as many insect visitors as numerous blooms offering less pronounced attractions. Especially significant was the rarity of the visits of the honeybee and other common species of Hymenoptera. It appeared as though nature had vainly provided powerful insect lures, excepting only those of conspicuous size and color. It is true that insects, some of them capable of transferring pollen from flower to flower, do visit beet flowers, but relatively their numbers are small and their visits few.

These breeding experiments necessitated the isolation and hand pollination of numerous beet flowers. Not infrequently, in spite of careful technic, it was found that single flowers which had been emasculated and protected by paper bags from pollination became fertilized and produced seed in a manner at the time inexplicable. Although the actual percentage of such cases was small, it was sufficient to attract attention and to cast doubt upon the thoroughness of the protection afforded by the bags. Not only is the beet flower protandrous, but numerous attempts of the writer to effect close fertilization by preserving the pollen until the stigma of the same flower should become receptive, then applying the pollen, have failed. The above-mentioned fertilization, therefore, could not have been accomplished by pollen from any one of the single flowers operated on, even had such pollen reached the stigma; in other words, the beet flower can not be self-fertilized. The most probable explanation for the fertilization of these isolated flowers was the

Note.—The investigations and experiments reported in this bulletin are of interest to horticulturists and plant breeders.

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unobserved access of minute pollen-bearing insects. None of the common visiting insects other than thrips is minute enough to gain entrance through the interstices between the mouth of the paper bag and the stem when the bag is tied closely about the beet spike. Thrips, however, are so tiny as scarcely to be visible to the naked eye, the mature larvæ being about $\frac{1}{27}$ inch long and only about $\frac{1}{70}$ inch long immediately after hatching; hence it seemed probable that some of these insects might have crawled up within the mouth of the tied bags and dropped on the stigmata of the isolated flowers some of the pollen they were carrying.

OCCURRENCE OF THRIPS ON BEET FLOWERS.

Besides several other species not identified, the Bureau of Entomology determined the following among specimens of thrips col-

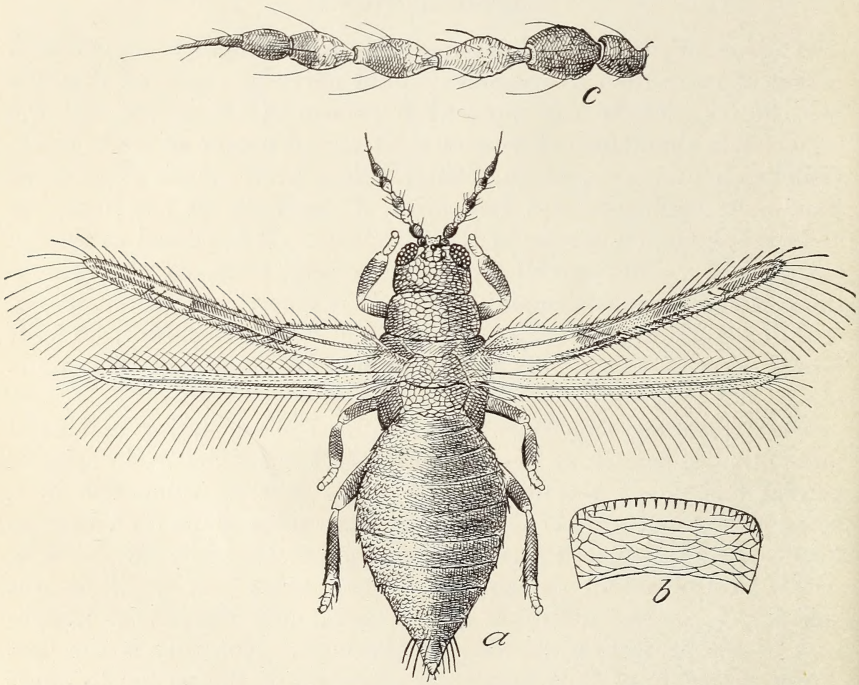
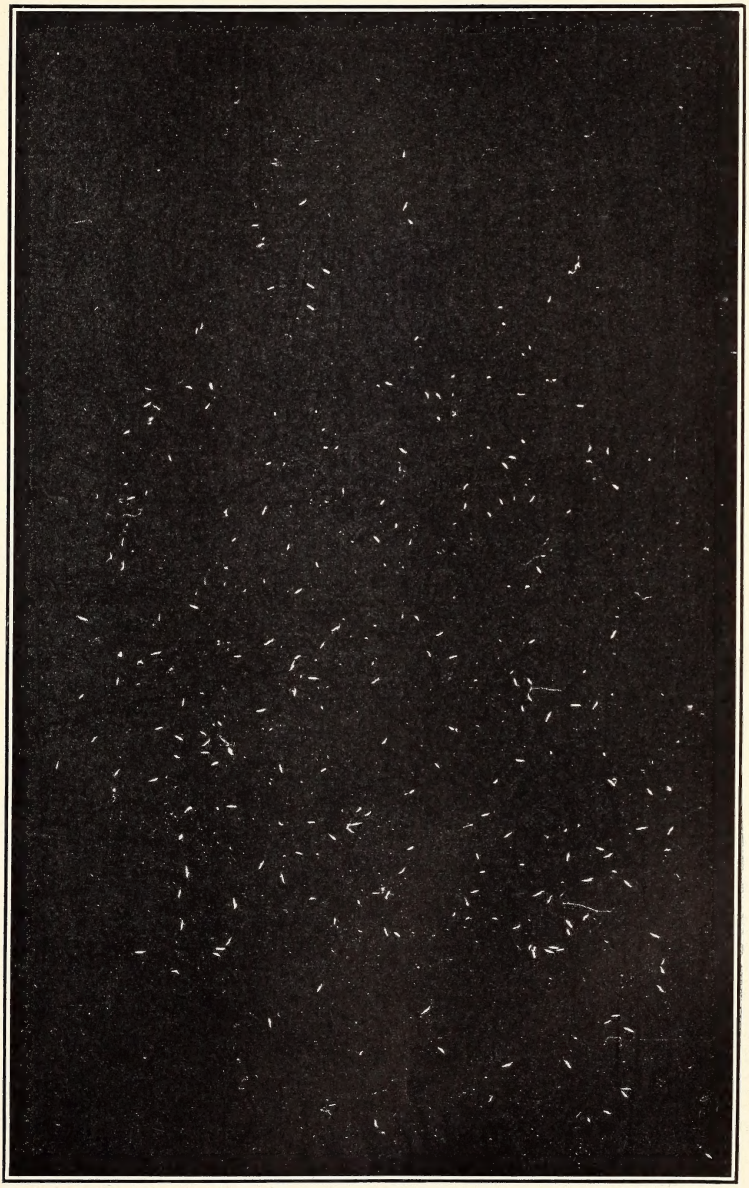


FIG. 1.—The bean thrips (*Heliothrips fasciatus*): *a*, Adult female; *b*, ventral side of abdominal segment of same; *c*, antenna of same. *a*, Greatly enlarged; *b*, *c*, more enlarged. (After Russell.)

lected from beet flowers at Garland, Utah, in 1909 and 1910: *Heliothrips fasciatus* L. (fig. 1), *Frankliniella fusca* Hinds, and *Frankliniella tritici* Fitch. The species most abundant during the seasons of 1911 and 1912 at Ogden, Utah, was *Thrips tabaci*, the onion thrips. The few observed at Jerome, Idaho, during the summer of 1913 have not yet been determined.

At Garland the seed beets were grown near fields of alfalfa, whence many of the thrips found on beets doubtless migrated, the same species



THRIPS TABACI DISLODGED FROM THE BEET FLOWERS SHOWN IN PLATE II. NATURAL SIZE. (ORIGINAL.)

BRANCHED SPIKE OF BEET FLOWERS FROM WHICH THE THRIPS SHOWN IN PLATE I WERE DISLODGED. NATURAL SIZE. (ORIGINAL.)

being exceedingly abundant in alfalfa blossoms. In Ogden the experimental plats were located in the heart of a trucking district, where many onions and other general truck crops are grown. At Jerome the beet plats were surrounded by alfalfa fields. At Garland these insects were fairly abundant. At Ogden in 1911 they were very abundant. This may be better appreciated by a glance at Plate I, which shows the thrips that were dislodged from the small branched spike depicted in Plate II after the spike of flowers had been exposed for a short time to the fumes of chloroform. Before the thrips had recovered from anesthesia the spike and its branches were distinctly outlined by the stupefied insects. Notes taken at the time read as follows:

August 7, 1912.—After treatment with chloroform, 85 thrips fell from a spike possessing 80 open flowers; from another branched spike 190 thrips were dislodged.

Inspection of beet flowers sometimes revealed as many as five or six thrips in a single perianth.

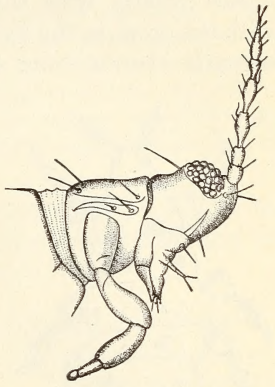


FIG. 2.—Side view of the head of a thrips, showing the mouth parts. Much enlarged. (After Moulton.)

In 1912, on the site of an old Chinese truck garden at Odgen, thrips became extraordinarily numerous during the late blooming period, when they fairly swarmed in and about the beet flowers. It was then ascertained that in addition to drinking the nectar and devouring the pollen they may also injure the floral organs.

Earlier studies of the injurious effects of various sucking insects, including aphides, red spiders, and thrips, on sugar beets, had established the fact that the last-named insects sustain their unenviable character on sugar beets also; they cause on young sugar beets a great diversity of leaf curls and distortions. On the spikes and bractlets of seed beets small silvery scars may be found as a result of their attacks. The thrips is more destructive than most sucking insects, because, not satisfied with merely puncturing, it tears and grubs up the surface tissues of its food plants with its powerful mouth cones, or proboscis (fig. 2), in order to release a more copious flow of the plant juices.[1] It reminds one of the actions of a hog.

These studies were extended to the observation of thrips on the inflorescence of sugar beets. The spikes and spikelets of the sugar beet, with their closely arranged spirals of flower clusters, are very numerous and afford excellent hiding places for these insects. It was found that as the period of most abundant bloom approached, thrips became increasingly numerous, partly through migration from

[1] Moulton, Dudley. The pear thrips and its control. United States Department of Agriculture, Bureau of Entomology, Bulletin 80, pt. 4, p. 54, 1912.

other plants, but more especially through breeding. Eggs are deposited and hatched on the spikes themselves. On hatching, the young larvæ quickly seek the flowers, doubtless attracted by the pungent fragrance of the nectar, and literally wallow in the nectar and pollen, avidly drinking the one and voraciously devouring the other.

Observations covering five seasons have shown that several species of Thysanoptera visit beet flowers and that the number of individuals varies greatly with the locality and general environments, notably with the crops in the vicinity. At Jerome, Idaho, in 1913, on land only recently cleared from sagebrush, thrips were rather scarce, although somewhat abundant in alfalfa in near-by fields. These insects have also been seen in moderate abundance on seed beets in Indiana and Michigan.

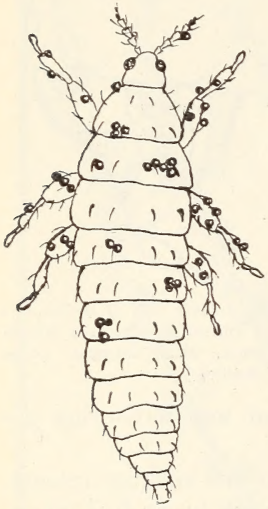


FIG. 3.—Larva of *Thrips tabaci* (second stage) taken from a sugar-beet flower. The insect carries numerous beet-pollen grains on its body. × 50. (Sketch of the larva after Russell.)

THRIPS AS POLLEN BEARERS.

The writer has been able to discover in the literature very little reference to thrips as a pollen bearer and no proof of its ability to bring about the fertilization of flowers.

Darwin was familiar with the visits of thrips and kept in mind the possibility that they might gain entrance through his nets.

Hermann Müller [1] records their occurrence in the flowers of several genera and species, but does not mention beets. In a paragraph on Thysanoptera he says that "probably few flowers, if any, are altogether exempt from their visits, and though they have seldom been detected in the conveyance of pollen, yet from their great abundance, their value as fertilizers must not be overlooked. It is almost impossible to exclude these tiny insects by means of nets. The Thysanoptera seek both pollen and honey. They seize a single pollen grain in their mandibles and convey it to the mouth."

Uzel,[2] in Bohemia, has noted the visits of several species of Thysanoptera among sugar and stock beets, but adduces no evidence in proof of the actual pollination of those flowers by thrips.

On August 3, 1911, at the experimental plats in Ogden, Utah, spikes of beet flowers were exposed to the fumes of chloroform to

[1] Müller, Hermann. The fertilisation of flowers. Tr. and ed. by D'Arcy W. Thompson, London, 1883, p. 44–45.

[2] Uzel, Heinrich. Über die Insekten, welche die Blüten der Zucker- und Futterrübe besuchen. Zeitschrift für Zuckerindustrie in Böhmen, Jahrg. 37, p. 182–197, 1913.

dislodge insects that might be harboring in them. As already stated, thrips in unsuspected number were thus removed. (Pls. I and II.) A microscopic examination of many of these—larvæ and adults—showed that without exception beet pollen grains were present on their bodies (fig. 3).

The original notes under this date are as follows:

August 3, 1911.—Discovered that *Thrips* sp. [later determined as *Thrips tabaci*] are exceedingly numerous on and among beet flowers. Some spikes were collected, and absorbent cotton sprinkled with chloroform was held over them to stupefy any insects that might be present. Thrips fell off and were microscopically examined. Without exception, each bore among its body hairs numerous sugar-beet pollen grains. Some open flowers were then examined, and thrips, as they recovered from their stupor, were observed to enter the perianth, where they moved about quite actively, traveling over every part. Many pollen grains were picked up by the insects' body hairs, others were dropped; pollen was also transferred from one insect to another when they came in contact one with another.

Almost at the close of the blooming period of beets, counts were made of the pollen grains borne by a number of thrips dislodged with chloroform from beet spikes, as shown in Table I.

TABLE I.—*Beet pollen grains on thrips, near the close of the blooming period.*

Stage of development of the insect.	Number of grains found on surface indicated.		
	Dorsal.	Abdominal.	Total.
Nymph	30	10	40
Adult	62	78	140
Do	53	82	135

These pollen grains were distributed over every part of their bodies, even along the antennæ. Nor do these figures represent unusual individuals. The blooming period was practically over at this time; pollen was therefore not very abundant. Both larval and adult thrips have since been seen to be literally covered with beet pollen.

EXPERIMENTS IN THE POLLINATION OF BEET FLOWERS.

The foregoing results were both interesting and surprising, and at once suggested, among others, the following queries:

(1) Do the thrips in this instance redeem themselves from their hitherto wholly evil reputation by playing an essential, or even an important, rôle in the fertilization of beet flowers? Or, do they simply convey pollen from one flower to another on the same plant and thus effect close pollination only?[1]

[1] Other experiments have shown close pollination of beet flowers to be almost absolutely ineffective in bringing about fertilization, which is undesirable even when successful. Self-fertilization is not possible. The term "self-fertilization" is here used to mean that resulting from the pollen of the same flower; "close pollination," or "close fertilization," that effected by the application of pollen from one flower to another on the same plant; "cross-pollination," that between any two plants.

(2) Inasmuch as they consume large quantities of pollen, do they thus work injury to beets?

(3) Do they injure the floral organs of beet flowers?

To be effective agents in the fertilization of beet flowers, they must do more than convey pollen from one flower to another on the same spike, stem, or plant; they must bring about true cross-pollination.

Although already late in the season when the foregoing observations were made, experiments were at once planned to ascertain whether pollination and fertilization might be effected through the agency of thrips. To this end several vigorous seed beets, still in bloom, were selected. On August 7 and 8, 1911, the largest buds on a number of spikes were emasculated, the smaller and more immature buds being trimmed off. This work was done at the stage when the sepals were just about to separate at the tips and disclose a tiny yellow spot of the anthers, and it was performed under a pollinating tent in order to exclude flying insects and wind-carried pollen (fig. 4). As each set of buds was emasculated it was at once covered with a white manila paper bag, 4 by 6 inches in size. A tuft of absorbent cotton was first wrapped carefully about the spike some inches below the buds. The bag was then drawn over the spike until the emasculated buds were situated inside the bag near the top, while the mouth of the bag reached well below the buds and came in contact with the wrapping of cotton. The mouth of the bag was then folded diagonally in such a manner as to pinch the cotton-wrapped stem in one corner; then it was folded a second time to make tight contact. Metal clips were finally set along the edge of the double fold to secure it (fig. 5). The stems bearing these spikes were tied to stakes to prevent too much movement and to keep them in an upright position. Before covering the spikes a close search was made for thrips or other small insects, any such being removed. The stigmata of these flowers became receptive three days later. Thrips were then collected from other beet flowers into small vials. As each lot was collected it was immediately transferred to one of the bagged spikes.

FIG. 4.—Pollinating tent of white sheeting, which may be completely closed and secured with hooks and eyes or buttons. (Original.)

FIG. 1.—FLOWERS OF SUGAR BEETS TO WHICH THRIPS HAD ACCESS. NATURAL SIZE. (ORIGINAL.)

FIG. 2.—SPIKES OF SUGAR-BEET FLOWERS ON CHECK PLANTS, WHICH REMAINED STERILE. NATURAL SIZE. (ORIGINAL.)

To accomplish this a slit was made in one side of the bag at least 2 inches below the buds of the inclosed spike, so that no pollen or thrips might fall upon the flowers when the vial was inverted over the slit, and the pollen-bearing thrips were jarred downward into the bag. This being done, the slit was closed with adhesive plaster, leaving the inclosed thrips free to seek the nectar and distribute the pollen they carried. About 25 thrips were put in each bag.

Three forms of control or checks were employed at this time:

(1) Spikes of emasculated buds were isolated, as above described, and left undisturbed.

(2) Similar spikes were isolated, and when the inclosed flowers had become receptive, slits were made in the bag and at once closed without introducing thrips.

(3) Spikes of buds were prepared as for emasculation and isolated without that operation being performed. These also were then left undisturbed.

One month later, all the bags were opened to examine the inclosed flowers. The time had been too brief for the maturation of seed, but it was ample for fertilization and for the development of seed to the milky stage. The results were as follows:

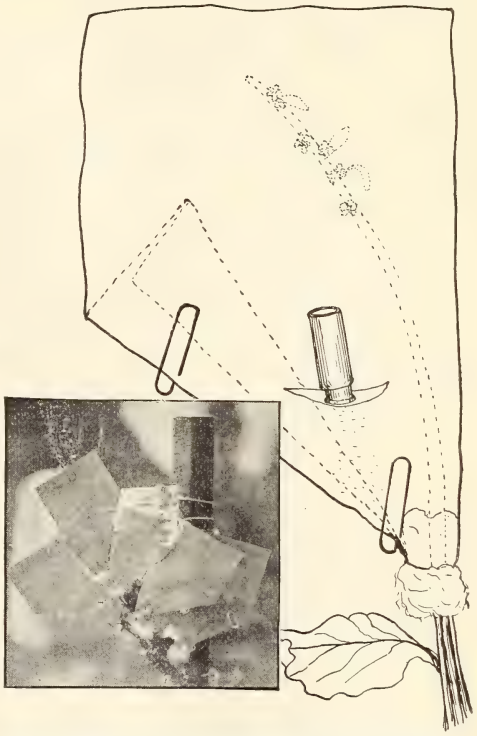


FIG. 5.—Spikes of beet flowers isolated by means of paper bags, showing the method of admitting pollen-bearing thrips through an opening. (Original.)

Every flower on the checks remained sterile, the sepals of some remaining green. In other cases the entire flower had withered (Pl. III, fig. 2). Among those to which thrips had been introduced, one set of flowers was lost; of a second set, 16.66 per cent of the flowers became fertilized and produced seed; a third showed 20 per cent of fertilization; and a fourth, 28.6 per cent. For the entire set, the percentage of effective pollination by thrips was 20.37 (Pl. III, fig. 1).

On August 26, 1911, eight spikes of wild-beet flowers were similarly treated. Three of these were used as checks. Thrips were placed with the others in the manner above described. Some of these spikes were afterwards broken off, but of those remaining none of the checks became fertilized; of those to which thrips had been admitted only one remained, and 20.5 per cent of its flowers had been fertilized and produced seed.

The flowers of a beet spike open successively; therefore, few at any one time attain the same stage of development. This fact not only limits the number of available buds on each spike, but also may reduce the percentage of effective hand pollination as much as 50 per cent. The above results may therefore be considered not only positive, but surprising. The complete notes of the results of this experiment are shown in Table II.

TABLE II.—*Pollination of beet flowers—experiment of August 26, 1911.*

Spike.	Description.	Flowers.		Seeds.		Remarks.
		On spike.	Sterile.	Number.	Per cent.	
No. 1a	Check	22	22	0	0	Not emasculated; spike dry and brown.
No. 2a	do	14	14	0	0	Do.
No. 2b	do	36	36	0	0	Emasculated.
No. 2c	do	22	22	0	0	Do.
No. 3a	do	10	10	0	0	Emasculated; stems and flowers green.
	Total	104	104	0	0	
No. 3b	Thrips admitted	7	5	2	28.6	
No. 3c	Missing					
No. 4a	Thrips admitted	12	10	2	16.66	
No. 4b	do	35	28	7	20.00	
	Total	54	43	11	20.37	For the entire set.
	Wild beets.					
No. 1	Check					
No. 2	do					
No. 4	do		All.	0	0	Broken off.
No. 3	Thrips admitted					Do.
No. 5	do					Do.
No. 6	do					Do.
No. 7	do					Do.
No. 8	do	24	19	5	20.83	

During the following season two similar experiments were carried out. The first experiment was made on June 26, 1912, when the plants were flowering abundantly. On this date two spikes were prepared as already described, except that the additional precaution was taken to spray thoroughly all parts of the flowers and spikes with water from an atomizer to remove any thrips that might be hidden there. Three days later thrips were collected and transferred to the bags. A month later complete notes were made, with the results shown in Table III.

On July 12, 1912, the second experiment was started in the same manner with three spikes, and a month later the data shown in Table III were secured.

These experiments demonstrate that thrips transferred from one flowering beet to another may carry sufficient pollen on their bodies to effect fertilization.

TABLE III.—*Pollination of beet flowers—experiments of June 26 and July 12, 1912.*

Experiment of June 26, 1912.						Experiment of July 12, 1912.					
Spike.	Description.	Flowers.		Seeds.		Spike.	Description.[1]	Flowers.		Seeds.	
		On spike.	Sterile.	Number.	Per cent.			On spike.	Sterile.	Number.	Per cent.
No. 1	Thrips admitted	18	6	12	66.66	No. 1	Thrips admitted	13	8	5	38.46
No. 2	do	14	4	10	71.14	No. 2	do	20	17	3	15
	Total[2]	32	10	22	68.75	No. 3	Check	20	20	0	0

[1] Of the 33 flowers to which thrips were admitted in this experiment, 24.24 per cent are shown to have been fertilized, while all the checks remained sterile.
[2] For entire set.

CROSS-POLLINATION BY THRIPS.

As already stated, other studies have shown that close pollination of beets rarely results in fertilization and that self-fertilization does not take place. To be of service to beets, thrips must therefore bring about cross-pollination. The writer has found the impression rather general that thrips do not travel from plant to plant to any great extent. On this point the following evidence from the writer's notes is available:

July 19, 1912.—A great number of thrips had been shaken from seed beets in full bloom into a large pan. In the slanting rays of the evening sun many of the adults, which are winged, could be seen to fly from the collecting pan and alight on adjacent plants. Their flight was sustained and fairly steady, though not nearly so rapid as that of gnats.

July 21, 1912.—Since attention was attracted to the flight of thrips, careful watching, when their wings glitter in the evening sunshine, revealed the fact that their flight from plant to plant is voluntary and frequent; this flight is well sustained, though very slow. They were seen to travel not only from one plant to the next, 4 feet away, but to more distant ones. The flight of many of these thrips was intercepted by a sheet of white paper, upon which they alighted. Some of them were chloroformed and examined. Pollen at this time was not very abundant, because the plants were long past the time of maximum bloom. Counts were made showing that 5 different thrips carried grains of pollen, as follows: No. 1, 5 grains; No. 2, 44 grains; No. 3, 3 grains; No. 4, 38 grains; No. 5, 4 grains.

July 23, 1912.—An examination of the seed beets in plat 2, where seed is almost ripe, showed an absence of thrips. The number of these insects on the plants now in bloom in plat 1 is immense. [Plat 1 lies about 50 feet north of plat 2. Many beets in plat 1 were planted later than those in plat 2 and were therefore still in bloom.] Thrips were fairly numerous in plat 2 when the plants there were in bloom; therefore it would appear that thrips migrate some distance in pursuit of pollen and nectar. An examination of plants in plat 1, some of which had been planted earlier than others, showed the earlier planted ones, now without bloom, to be devoid of thrips.

This study established the fact that not only are thrips capable of collecting and carrying pollen on their bodies and of effecting cross-

pollination and subsequent fertilization when transferred from one flowering beet to another, but that they voluntarily travel from plant to plant and carry pollen throughout a sustained flight.

From this evidence there can remain no doubt that these insects are capable of playing an important rôle in the pollination of beet flowers. May it not be a very significant one? It is known that in certain parts of Europe and the United States beets have sometimes, perhaps frequently, failed to produce seed, although an abundance of bloom appeared. It seemed possible that the presence or absence of thrips in great number might in part be responsible for this phenomenon. Subsequent observations, however, afford evidence in disproof of this theory. It is safe to say that thrips undoubtedly assist in the pollination of beet flowers, perhaps to a greater extent than any other species of insect. It can scarcely be doubted that they perform a like service for many other plants.

INJURY TO SEED BEETS.

Thrips feed avidly upon the nectar and pollen of beets, but beet pollen is so abundant that unless thrips be present in enormous numbers they apparently do no damage to the floral organs, preferring as food the nectar and pollen. However, should they become extraordinarily numerous, as was the case at Ogden in 1912 during the latter part of the season, it would seem that the nectar and pollen are not sufficiently abundant to supply their truly voracious appetites. They then attack the more delicate and succulent parts of the flowers. Sometimes the styles are cut through at the base, but more frequently the papillæ, with which the lobes of the stigma are thickly studded, are torn to pieces. Furthermore, they may devour so much pollen as to interfere with both wind and insect pollination by too greatly diminishing the supply. Thrips move actively from flower to flower of the same spike, from spike to spike and stem to stem of the same plant, and in this way bring about much more close pollination than cross-pollination, and in fact effect all the close pollination and fertilization of which the plant is susceptible. This in itself is undesirable and even harmful. Close fertilization has been shown to cause degeneration among beets, even in the sense of pollination and fertilization between different individuals of the same progeny.

TROUBLE TO PLANT BREEDERS.

The writer has experimentally shown that the larvæ of thrips in all stages readily pass through the meshes of fine silk chiffon and much more readily through the net, cloth, and sheeting frequently used by horticulturists and plant breeders to isolate flowers designed to be hand-pollinated. He has also been able to demonstrate that

they actually do effect pollination and fertilization after passing through such covers.

The following is an instance of what might be expected to occur through the agency of thrips: The horticulturist of a well-known firm of seedsmen in the United States noted that his asters became fertilized although covered with cloth bags. The writer suggested that thrips might be responsible for this. The horticulturist replied in part that "the aster flowers were merely covered with coarse-meshed cloth to see if they were self-fertile. Insects as small as thrips would not have been excluded. We merely learned that the fertilization of asters is not dependent on the insects—mostly beetles—that one ordinarily sees on the flowers."

The horticulturist and plant breeder may not disregard these insects. They introduce an element of uncertainty to be guarded against with the utmost care and circumspection. Their minute size, inconspicuous color, great numbers, and the fact that they are almost ubiquitous make them a factor to be reckoned with by every worker along these lines and necessitate the development of special precautions and technic.

Covers of net, cloth, and sheeting afford no real protection against them; even paper bags must be applied with great care. The writer found the method described and illustrated in connection with these experiments to be simple and efficacious.

It is as necessary to rid the isolated portion of plant and flower of thrips already present as to prevent the access of others after isolation. In these experiments the practice was made of carefully scrutinizing each spike of buds or flowers before covering it and brushing off any thrips that might be present with a camel's-hair or sable brush, sometimes also spraying the spike thoroughly with water. In the summer of 1912 the use of nicotine sulphate also was tried, as shown in the following notes:

July 24, 1912.—At this late blooming period, thrips have become exceedingly numerous on all spikes in bloom; they interfere seriously with pollination work. To ascertain whether a simple, practical method might be available to rid the individual spikes completely of these pests, the following experiment was carried out: Some spikes, badly infested with thrips, were selected. Before operating on the spikes, they were immersed in the following solution: Water, 2 pints; nicofume (nicotine sulphate), 1 tablespoonful.

Spikes 1, 2, and 3 (in their normal condition, i. e., bearing flowers of all stages—buds, flowers just opening, and flowers already fertilized) were immersed in the above solution 10 seconds; then they were at once isolated with manila paper bags in the manner previously described.

Spike 4, with selected buds emasculated, was treated with nicofume like the preceding, bagged, and (when stigmata had become receptive) pollinated.

Spikes 5 and 6 were treated like No. 4, but not pollinated.

Spike 7 was merely shaken and flowers blown upon to dislodge thrips; flowers emasculated.

August 19, 1912.—All spikes examined.

Nos. 1, 2, and 3 in good condition; no signs of thrips or other insects; no injury from nicofume; good seed formed.

No. 4. No injury from nicofume apparent; no evidence of thrips or other insects; emasculated July 24, 1912; pollinated July 27, 1912; of 10 flowers pollinated 8 produced seed.

No. 5. General condition similar to No. 4; emasculated July 24, 1912; not pollinated; 13 flowers emasculated; all remained sterile.

No. 6. Similar to No. 5; all flowers remained sterile.

No. 7. Check; spike dead.

This experiment shows that the treatment with nicotine solution did not perceptibly injure beet flowers and that it at the same time removed thrips from them.

CONCLUSION.

From these experiments it is seen that these minute insects, the numerous species of Thysanoptera, some of which more or less injuriously infest practically all our plants, are also active agents in pollination. Among beet flowers they are frequently very numerous indeed, effecting both close pollination and cross-pollination upon them. However, after taking into account the various forms of injury they do, it is doubtful whether the balance remains in their favor in regard even to beets. Under ordinary conditions, in fields of commercial seed beets, it is believed that on the whole their work is beneficial; but should they become excessively numerous, they sustain their reputation as one of our really destructive pests. To the horticulturist and plant breeder they are pests of the worst type, necessitating constant watchfulness and a refined technic in all pollination work.

The suggestion is ventured that certain supposed mutations may really have been the result of unsuspected cross-pollination by means of one or another species of thrips, whether in cereals supposedly not susceptible to cross-pollination without the intervention of man or in flowers which were thought to have been isolated against cross-pollination.

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